Te...   Report S... on the
B... osystem-A... sphere Study (BOREAS)

...ll, *Editor*

...86

...AS Level-0 ER-2

...A. *Newcomer, and R. Dominguez*

The NASA STI Program Office ... in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results ... even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at http://www.sti.nasa.gov/STI-homepage.html

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA Access Help Desk at (301) 621-0134

- Telephone the NASA Access Help Desk at (301) 621-0390

- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320

NASA/TM—2000–209891, Vol. 86

Technical Report Series on the
Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall, Editor

Volume 86
BOREAS Level-0 ER-2
Navigation Data

Richard Strub, Raytheon ITSS
Roseanne Dominguez, ATAC, Inc., NASA Ames Research Center, Moffett Field, California
Jeffrey A. Newcomer, Raytheon ITSS, NASA Goddard Space Flight Center, Greenbelt, Maryland

Available from:

BOREAS Level-0 ER-2 Navigation Data

Richard Strub, Roseanne Dominguez, Jeffrey A. Newcomer

Summary

The BOREAS Staff Science effort covered those activities that were BOREAS community-level activities or required uniform data collection procedures across sites and time. These activities included the acquisition, processing, and archiving of aircraft navigation/attitude data to complement the digital image data. The level-0 ER-2 navigation data files contain aircraft attitude and position information acquired during the digital image and photographic data collection missions. Temporally, the data were acquired from April to September 1994. Data were recorded at intervals of 5 seconds. The data are stored in tabular ASCII files.

Note that the level-0 ER-2 navigation data are not contained on the BOREAS CD-ROM set. An inventory listing file is supplied on the CD-ROM to inform users of the data that were collected. See Section 15 for information about how to acquire actual level-0 ER-2 navigation data.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification
BOREAS Level-0 ER-2 Navigation Data

1.2 Data Set Introduction
The BOReal Ecosystem-Atmosphere Study (BOREAS) Staff Science effort covered those activities that were BOREAS community-level activities or required uniform data collection procedures across sites and time. These activities included the acquisition, processing, and archiving of aircraft navigation/attitude data to complement the digital image data.

1.3 Objective/Purpose

The ER-2 navigation data set consists of navigation parameters gathered by the aircraft's onboard systems in support of the payload instruments. The purpose of the data is to provide general aircraft positioning information and aircraft attitude information during data collection activities.

1.4 Summary of Parameters

The data include times and georeferencing information that can be used to determine temporal and spatial coordinates associated with each measurement collected from the onboard instruments.

1.5 Discussion

The ER-2 navigation data set consists of navigation parameters gathered by the aircraft's onboard systems in support of the payload instruments. It includes times and georeferencing information that can be used to determine temporal and spatial coordinates associated with each measurement collected from the above instruments.

1.6 Related Data Sets

BOREAS Level-0 ER-2 Aerial Photography
BOREAS Level-0 AOCI Imagery: Digital Counts in BIL Format
BOREAS Level-0 Daedalus TMS Imagery: Digital Counts in BIL Format
BOREAS RSS-18 Level-1B AVIRIS Imagery: At-sensor Radiance in BIL Format

2. Investigator(s)

2.1 Investigator(s) Name and Title

BOREAS Staff Science

2.2 Title of Investigation

BOREAS Staff Science Aircraft Data Acquisition Program

2.3 Contact Information

Contact 1:
Jeffrey S. Myers
Aircraft Data and Sensor Facilities
NASA Ames Research Center
MS 240-6 (Bldg. 240, Rm. 219)
Moffett Field, CA 94035-1000
(415) 604-6253
(415) 604-4987 (fax)
jmyers@arc.nasa.gov

Contact 2:
Jeffrey A. Newcomer
Raytheon ITSS
Code 923
NASA GSFC
Greenbelt, MD 20771
(301) 286-7858
(301) 286-0239 (fax)
Jeffrey.Newcomer@gsfc.nasa.gov

3. Theory of Measurements

The National Aeronautics and Space Administration (NASA) at Ames Research Center (ARC) maintains a variety of aircraft and sensor systems dedicated to support of remote sensing research. Among these is the Lockheed ER-2 (U-2R). The ER-2 has carried the Moderate-Resolution Imaging Spectrometer (MODIS) Airborne Simulator (MAS), the Multispectral Atmospheric Mapping Sensor (MAMS), the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS), the Thematic Mapper Simulator (TMS), the Airborne Ocean Color Imager (AOCI), and the Thermal Infrared Multispectral Scanner (TIMS). For the BOREAS project, the TMS, AOCI, and AVIRIS sensors flew aboard the ER-2.

Navigation parameters provided by the Litton LTN-92 Inertial Navigation System (INS) includes latitude/longitude, altitude, air speed, pitch, roll, heading, wind speed and direction, and static air temperature. The data were recorded in 5-second intervals.

4. Equipment

4.1 Sensor/Instrument Description

4.1.1 Collection Environment
The INS on the ER-2 is a Litton LTN-92. The LTN-92 comprises three separate units: the Inertial Navigation Unit (INU), the Control/Display Unit (CDU), and the Mode Select Unit (MSU). Three 28-cm ring laser gyros and a triad of force rebalanced accelerometers make up the LTN-92's instrument cluster. The system accepts Area Navigation (RNAV), Global Positioning System (GPS), or manual position updates, plus INS mixing for improved performance. The Litton Web site (http://www.littoncorp.com/html/newsflash/06_14_97.htm) can be referenced for more information.

The system operates by sensing accelerations from a gyro-stabilized, all-attitude platform. This information is integrated by a digital computer to provide an indication of present position (latitude and longitude), attitude data (pitch and roll), and course line computation referenced to great circle routes. The ER-2 has no room for auxiliary personnel; the LTN-92 INU, the instrument control panel, and the temperature and pressure units are directly connected to the data recorder in the payload area.

4.1.2 Source/Platform
The NASA ER-2 is a high-altitude, single-pilot aircraft based at ARC in Moffett Field, CA, and is deployed globally in support of a variety of atmospheric research projects. It has a maximum altitude of 70,000 feet (21 km), a range of 3,000 nautical miles, a maximum flight duration of 8 hours (nominal 6.5 hours), and a top speed of 410 knots true air speed. The aircraft accommodates about 2,700 pounds of payload and offers the following science support systems:
- Inertial navigation
- Satellite NBS Time Code receiver
- Navigation data recording system
- Real-time telemetry data link

4.1.3 Source/Platform Mission Objectives
For BOREAS, the primary ER-2 mission objective was to collect various Earth surface data in coordination with satellite overpasses for data verification and integration studies. A secondary objective was to collect data at key times when the satellites were not within range of specific sites. The ER-2 was based in Spokane, WA, and could be deployed from there to take advantage of anticipated good data collection conditions. The navigation data provide in-flight geographic location and attitude information for the onboard sensors.

4.1.4 Key Variables
The key parameters used by BOREAS Information System (BORIS) staff and investigators are geographic location, time, platform attitude, altitude, aircraft pitch and roll, and temperature in proximity to the aircraft.

4.1.5 Principles of Operation
The INS on the ER-2 operates by sensing accelerations from a gyro-stabilized, all-attitude platform. This information is integrated by a digital computer to provide an indication of present position (latitude and longitude), attitude data (pitch and roll), and course line computation referenced to great circle routes.

4.1.6 Sensor/Instrument Measurement Geometry
Aboard the ER-2, navigation parameters are recorded at 5-second intervals. The data buffer servicing the navigation recorder samples the particular parameter between records, but is precisely correct only at some point between records. Each parametric measurement is recorded as a count in a 16-bit word; consequently, the conversion of that count to an engineering unit defines the precision. The precision of each measurement is tabulated below.

```
Parameter            Precision
---------            ---------
Julian Date          One day
Time                 One second
Latitude             0.33 minutes of angle (2002.6 feet)
Longitude            0.33 minutes of angle (2002.6 feet)
N-S Velocity         0.1 knot
E-W Velocity         0.1 knot
True Heading         0.0054932 degrees of an angle
Ground Speed         0.1 knot
Vertical Velocity    0.025 feet/second
Altitude             2.92749 feet (pressure altitude)
True Air Speed       0.0152588 knot
Pitch                0.0054932 degrees of an angle
Roll                 0.0054932 degrees of an angle
Computed:
Ground Speed         1.0 nautical mile per hour
Wind Speed           1.0 nautical mile per hour
Wind Direction       1.0 degree
Vertical Velocity    1.0 foot per second
Climb Angle          1.0 degree
Air Temperature      0.1 degree centigrade
```

The accuracy of the X-Y-Z position as recorded by the navigation system is limited by the frequency and accuracy of the Tactical Air Navigation (TACAN)-based updates to the inertial system and the accuracy of the recorded altitude. In the conterminous United States, updates occur frequently and are based on strong relative geometry because of the density of TACAN stations, resulting in errors of less than 0.1 nautical mile in X and Y (less error than the precision of the recording system). Altitude is based on barometric pressure with standard pressure defined as 29.92 inches of mercury. Consequently, the actual altitude above mean sea level will vary with current atmospheric conditions and the actual altitude above terrain with the terrain elevation.

4.1.7 Manufacturer of Sensor/Instrument
ARC personnel built the navigation data recorder specifically for NASA's ER-2 fleet.

LTN-92 INU
Litton Industries, Inc.
Woodland Hills, CA 91367-6675

4.2 Calibration

4.2.1 Specifications
None given.

4.2.1.1 Tolerance
None given.

4.2.2 Frequency of Calibration
None given.

4.2.3 Other Calibration Informati

5. Data Acquisition Methods

The ER-2 has no room for auxiliary personnel; the LTN-92 INV, the GPS, the instrument control panel, and the temperature and pressure units are connected to the payload area by RS232 and Aeronautical Radio, Inc. (ARINC) 429 data buses.

Data are recorded serially as a flux change on both track 1 and track 2, with a flux change on track 1 representing a logic one and a flux change on track 2 representing a logic zero. Data words are grouped with 16 bits per word and are separated by a three-step gap in which no flux changes occur on either track. After 1316-bit words (or up to 21 words, depending upon how many analog channels have been recorded), a 12-bit end-of-file gap is recorded (no flux changes). The order of words is as follows:

```
WORD            DESCRIPTION
Serial Number, Flags, Julian Date
Clock
Latitude
Longitude
N-S Velocity
E-W Velocity
True Heading
Ground Speed (valid data only with standard INS)
Vertical Velocity (valid data only with high-resolution INS)
Altitude
True Air Speed
Pitch
Roll
14-21      Analog Inputs (optional)
```

For more detailed information on the Cassette Data Format see Guillot, 1985.

6. Observations

6.1 Data Notes
None. Pertinent in-flight comments are recorded in the digital data records.

6.2 Field Notes
Flight summary reports and verbal records on videotapes are available from the ER-2 flights.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage
The BOREAS level-0 ER-2 navigation data were collected primarily as the ER-2 flew over portions of the Southern Study Area (SSA) and the Northern Study Area (NSA) during its image data acquisition missions. The SSA and the NSA are located in the southwest and northeast portions of the overall BOREAS region. Some navigation data exist in the data set that cover the BOREAS transect area between the SSA and NSA and areas outside the BOREAS region.

```
The North American Datum of 1983 (NAD83) corner coordinates of the SSA are:

                Latitude      Longitude
                --------      ---------
Northwest       54.321 N      106.228 W
Northeast       54.225 N      104.237 W
Southwest       53.515 N      106.321 W
Southeast       53.420 N      104.368 W


The NAD83 corner coordinates of the NSA are:

                Latitude      Longitude
                --------      ---------
Northwest       56.249 N       98.825 W
Northeast       56.083 N       97.234 W
Southwest       55.542 N       99.045 W
Southeast       55.379 N       97.489 W
```

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
Spatial resolution is not strictly applicable to ER-2 navigational data. The sampling rate for each portion of the navigation data can be combined with aircraft position, speed, and altitude to derive a spatial component for each data sample. However, because of the 5-second duration between each navigation parameter, interpolating the navigation data to specific lines in the image data may have limited usefulness.

7.1.4 Projection
The BOREAS level-0 ER-2 navigation data contain latitude and longitude coordinates in the parameter set. Although the latitude and longitude coordinates could be used to calculate coordinates for any map projection, BORIS staff did not assess their accuracy and therefore cannot make any statements about their validity.

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
The data were collected during BOREAS' Focused Field Campaign (FFC) and three Intensive Field Campaigns (IFCs), covering the period from 19-Apr-1994 through 17-Sep-1994. The ER-2 collected various image data sets over the BOREAS sites in 1996, but no navigation data were delivered to BORIS.

7.2.2 Temporal Coverage Map

```
   IFC#              Dates
  -----       --------------------------
  FFC-T       16-Apr-1994 -- 20-Apr-1994
  IFC-1       23-May-1994 -- 08-Jun-1994
  IFC-2       21-Jul-1994 -- 08-Aug-1994
  IFC-3       08-Sep-1994 -- 17-Sep-1994
```

7.2.3 Temporal Resolution
All of the parameters in the navigation data were collected at intervals of 5 seconds.

7.3 Data Characteristics

7.3.1 Parameter/Variable
A listing of the navigation data file parameters is given in Section 8.2. The parameters contained in the inventory listing file on the CD-ROM are:

```
        Column Name
------------------------------
SPATIAL_COVERAGE
DATE_OBS
START_TIME
END_TIME
ER2_MISSION_ID
CRTFCN_CODE
```

7.3.2 Variable Description/Definition
A detailed description of the navigation data parameters is given in Section 8.2. The parameters in the CD-ROM inventory listing are:

Column Name	Description
SPATIAL_COVERAGE	The general term used to denote the spatial area over which the data were collected.
DATE_OBS	The date on which the data were collected.
START_TIME	The starting Greenwich Mean Time (GMT) for the data collected.
END_TIME	The ending Greenwich Mean Time (GMT) for the data collected.
ER2_MISSION_ID	The mission identifier assigned to the ER2 mission in the form of YY-DDD where YY is the last two digits of the fiscal year, and DDD is the deployment number. An example would be 94-120.

```
CRTFCN_CODE                                    The BOREAS certification level of the data.
                                               Examples are CPI (Checked by PI), CGR (Certified
                                               by Group), PRE (Preliminary), and CPI-??? (CPI
                                               but questionable).
```

7.3.3 Unit of Measurement

A detailed description of the navigation data parameter units is given in Section 8.2. The measurement units for the parameters contained in the inventory listing file on the CD-ROM are:

```
        Column Name                              Units
-------------------------------    ------------------------------------------------------
SPATIAL_COVERAGE                   [none]
DATE_OBS                           [DD-MON-YY]
START_TIME                         [HHMM GMT]
END_TIME                           [HHMM GMT]
ER2_MISSION_ID                     [none]
CRTFCN_CODE                        [none]
```

7.3.4 Data Source

A detailed description of the navigation data files and their content is given in Section 8.2. The sources of the parameter values contained in the inventory listing file on the CD-ROM are:

```
        Column Name                              Data Source
-------------------------------    ------------------------------------------------------
SPATIAL_COVERAGE                   [Constant software parameter value]
DATE_OBS                           [Navigation data files]
START_TIME                         [Navigation data files]
END_TIME                           [Navigation data files]
ER2_MISSION_ID                     [ER2 mission information]
CRTFCN_CODE                        [Constant data base value]
```

7.3.5 Data Range

The range of values for the parameters in the actual navigation data files was not tabulated. The following table gives information about the parameter values found in the inventory table on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SPATIAL_COVERAGE	N/A	N/A	None	None	None	None
DATE_OBS	19-APR-94	17-SEP-94	None	None	None	None
START_TIME	1310	1630	None	None	None	None
END_TIME	1920	2215	None	None	None	None
ER2_MISSION_ID	94-079	94-143	None	None	None	None
CRTFCN_CODE	PRE	PRE	None	None	None	None

```
Minimum Data Value -- The minimum value found in the column.
Maximum Data Value -- The maximum value found in the column.
Missng Data Value  -- The value that indicates missing data. This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the attempt was unsuccessful.
Unrel Data Value   -- The value that indicates unreliable data.  This is used
                      to indicate an attempt was made to determine the
                      parameter value, but the value was deemed to be
```

```
                        unreliable by the analysis personnel.
Below Detect Limit  -- The value that indicates parameter values below the
                        instruments detection limits.  This is used to
                        indicate that an attempt was made to determine the
                        parameter value, but the analysis personnel determined
                        that the parameter value was below the detection
                        limit of the instrumentation.
Data Not Cllctd     -- This value indicates that no attempt was made to
                        determine the parameter value.  This usually
                        indicates that BORIS combined several similar but
                        not identical data sets into the same data base table
                        but this particular science team did not
                        measure that parameter.

Blank -- Indicates that blank spaces are used to denote that type of value.
N/A   -- Indicates that the value is not applicable to the respective column.
None  -- Indicates that no values of that sort were found in the column.
------------------------------------------------------------------------
```

7.4 Sample Data Record

   A sample data record for the level-0 ER-2 navigation data is not available here. The following are the records from the level-0 ER-2 navigation data inventory table on the CD-ROM:

```
SPATIAL_COVERAGE,DATE_OBS,START_TIME,END_TIME,ER2_MISSION_ID,CRTFCN_CODE
'SSA',19-APR-94,1630,2215,'94-079','PRE'
'NSA',20-APR-94,1555,2155,'94-080','PRE'
'TRANSECT',20-APR-94,1555,2155,'94-080','PRE'
'NSA',28-APR-94,1445,2050,'94-082','PRE'
'TRANSECT',28-APR-94,1445,2050,'94-082','PRE'
'NSA',08-JUN-94,1345,1945,'94-102','PRE'
'TRANSECT',08-JUN-94,1345,1945,'94-102','PRE'
'SSA',21-JUL-94,1500,2040,'94-120','PRE'
'NSA',04-AUG-94,1310,1920,'94-123','PRE'
'SSA',04-AUG-94,1310,1920,'94-123','PRE'
'TRANSECT',04-AUG-94,1310,1920,'94-123','PRE'
'NSA',08-AUG-94,1314,1937,'94-124','PRE'
'SSA',08-AUG-94,1314,1937,'94-124','PRE'
'TRANSECT',08-AUG-94,1314,1937,'94-124','PRE'
'SSA',16-SEP-94,1500,2100,'94-142','PRE'
'NSA',17-SEP-94,1355,2005,'94-143','PRE'
'TRANSECT',17-SEP-94,1355,2005,'94-143','PRE'
'SSA',17-SEP-94,1355,2005,'94-143','PRE'
```

8. Data Organization

8.1 Data Granularity
   The smallest unit of level-0 ER-2 navigation data is all the ER-2 navigation information collected during the ER-2 flights over the BOREAS areas. All nine of the data files are in a single tar file on a single tape for distribution.

8.2 Data Format(s)
   The CD-ROM inventory listing file consists of numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no

spaces between the fields.

The data are contained in a single tar file and after extraction (tar -xvf) can be seen correctly if unblocked using a block size of 150. (dd if=in_fn ibs=150 cbs=150 obs=150 conv=unblock of=out_fn).

```
FLIGHT 94-079  DATE 19-APR-94:16:30
FLIGHT 94-080  DATE 20-APR-94:15:55
FLIGHT 94-082  DATE 28-APR-94:14:45
FLIGHT 94-102  DATE 08-JUN-94:13:45
FLIGHT 94-120  DATE 21-JUL-94:15:00
FLIGHT 94-123  DATE 04-AUG-94:13:10
FLIGHT 94-124  DATE 08-AUG-94:13:14
FLIGHT 94-142  DATE 16-SEP-94:15:00
FLIGHT 94-143  DATE 17-SEP-94:13:55
```

Each data file contains a header record that is formatted as described in the following table:

```
        U2/USER PLUS DIGITIZED ANALOG VALUES
                  HEADER INFORMATION


CHARACTERS      CONTENTS
----------      --------
RECORD 1
  2 - 7         "FLIGHT"
  9 - 14        The flight identifier, which consists of the last two digits of
                the fiscal year, a dash, and a three-digit unique number that
                identifies the flight within the fiscal year (e.g., 92-001)
 17 - 20        "DATE"
 22 - 29        The date of the flight at liftoff, in the form MM/DD/YY, where
                MM gives the number of the month
                DD gives the day
                YY gives the last two digits of the current year
 32 - 34        "A/C"
 36 - 38        Tail number of the aircraft (706, 708, or 709)
 41 - 47        "TAKEOFF"
 49 - 56        The takeoff time, in the form HH:MM/DD, where
                HH gives the hour (24-hour clock)
                MM gives the minute
                DD gives the day of the month at takeoff
 59 - 62        "LAND"
 64 - 71        The landing time, in the same form as "TAKEOFF," except that
                DD gives the day of the month at landing
 82 - 101       "RECORDER UNIT NUMBER"
103             ID number of the navigation data recorder
104 - 200       Blank

RECORDS 2 - 5 Title that serves to label the contents of the data records.
NOTE: Characters not explicitly mentioned here are filled with blanks; i.e.,
      the American Standard Code for Information Interchange (ASCII) code for
      "space."
(END of Table E-6A)
```

The data part of each file is formatted as described in the following table:

```
        U2/USER PLUS DIGITIZED ANALOG VALUES
        DATA RECORD FORMAT
        (English Units)
CHARACTER       CONTENTS
---------       --------
 02 - 12        The time and day in the form HH:MM:SS/DD, where
                HH gives the hour (24-hour clock)
                MM gives the minute
                SS gives the second
                DD gives the day of the month
 15             Time source indicator
                "G"  -- from Geostationary Operational Environmental Satellite
(GOES)
                "I"  -- Internal time source
 18 - 25        Latitude,    hHH:MM.t, as follows:
 18                 h        -- hemisphere, "N" for northern, or "S" for southern
 19 - 20            DD       -- Degrees of latitude
 21                 :        -- separator between degrees and minutes
 22 - 25            MM.t     -- Minutes and tenths of minutes of latitude
                             (with a decimal point)
 27 - 35        Longitude, hDDD:MM.t, as follows:
 27                 h        -- hemisphere, "W" for western, or "E" for eastern
 28 - 30            DDD      -- Degrees of longitude
 31                 :        -- separator between degrees and minutes
 32 - 35            MM.t     -- Minutes and tenths of minutes of longitude
                             (with a decimal point)
 37 - 41        Altitude, in feet (from 0 - 70000)
 42                 "space"  if below 70,000 feet, or
                    "+" if over 70,000 feet, (if over 70,000 feet, the
                    altitude (37-41) will contain 70000)
 45 - 47        True air speed, in nautical miles per hour
 49 - 53        Aircraft pitch, in degrees, given to tenths (with a decimal
                point);  positive indicates nose up
 55 - 59        Aircraft roll, in degrees, given to tenths (with a decimal
                point;  positive indicates right roll; (i.e., right wing down)
 61 - 66        True heading, in degrees, given to tenths (with a decimal
                Point);  zero degrees indicates north, positive to the
                east of north  (90 indicates due east; 180 indicates
                south; and 270 indicates west)
 67 - 72        North-South velocity, in nautical miles per hour
 74 - 77        East-West velocity, in nautical miles per hour
 79 - 82        Vertical velocity, in feet per second
 85 - 87        Ground speed, in nautical miles per hour
 94 - 96        Computed ground speed, in nautical miles per hour (square
                root of the sum of the squares of the north-south and
                east-west velocities)
100 - 103       Computed wind speed, in nautical miles per second (the vector
                difference of the true air speed and true heading and
                north-south and east-west velocities
107 - 109       Computed wind direction, in degrees from north (clockwise is
                positive)
113 - 116       Computed vertical velocity (in feet per second) computed
```

```
                    from the altitude difference and time difference
                    between consecutive records
122 - 124           Computed angle of attack (degrees); i.e., arcsine (vertical
                    velocity divided by ground speed)
134 - 138           Static air temperature in degrees C, computed from the first
                    digitized analog value, if recorded
```

9. Data Manipulations

9.1 Formulae
None.

9.1.1 Derivation Techniques and Algorithms
None.

9.2 Data Processing Sequence

9.2.1 Processing Steps
BORIS staff processed the level-0 ER-2 navigation data by extracting pertinent header information from the navigation file and loading the online data base with needed information.

9.2.2 Processing Changes
ARC applied no special or additional processing to the ER-2 navigation data from BOREAS.

9.3 Calculations

9.3.1 Special Corrections/Adjustments
ARC made no special adjustments or offsets to the data.

9.3.2 Calculated Variables
ARC made no special adjustments or offsets to the data.

9.4 Graphs and Plots
None.

10. Errors

10.1 Sources of Error
The data buffer servicing the navigation recorder samples the particular parameter between records, but is precisely correct only at some point between records. Each parametric measurement is recorded as a count in a 16-bit word; consequently the conversion of that count to an engineering unit defines the precision.

10.2 Quality Assessm10.2.1 Data Validation by Source

Data distribution to NASA ARC occurs at the conclusion of the deployment. Data tapes are presented in total for documentation and archive. Data evaluation consists primarily of identifying component failure (i.e., radar altitude, GPS values, and pressure measurements).

10.2.2 Confidence Level/Accuracy Judgment
The quality of the data is judged to be good.

10.2.3 Measurement Error for Parameters
See Sections 4.1.6 and 8.2.

10.2.4 Additional Quality Assessments
BORIS staff imported selected navigation files into a spreadsheet and graphed the values to check for reasonableness.

10.2.5 Data Verification by Data Center
BORIS staff reviewed the contents of the data files for consistency and used portions of the information to inventory and describe the data in the relational data base.

11. Notes

11.1 Limitations of the Data
None.

11.2 Known Problems with the Data
None.

11.3 Usage Guidance
The tar file should be copied from tape to disk. All nine ASCII files are contained in a single tar file and should be extracted (tar -xvf filename). Each file should then be placed into 150-byte records. This can be accomplished by the UNIX command dd:

dd if=nav.94-123 of=filename ibs=150 cbs=150 obs=150 conv=unblock

The files will then appear as 19 ASCII columns with a 5-line header.

11.4 Other Relevant Information
Not applicable.

12. Application of the Data Set

The ER2 navigation data could be used: 1) To possibly improve the positional location of the aircraft scanner data and 2) As inputs to software for automated geometric and geographic correction of the aircraft scanner data. As a word of caution, the accuracy and precision of these data are not as well known as those from the C130 aircraft and in addition, it is not known if the frequency of navigation observations is sufficient to properly correct distortions in the scanner data.

13. Future Modifications and Plans

No modification is planned for the ER-2 navigation data currently logged in the BORIS data base.

14. Software

14.1 Software Description
The UNIX dd command is useful in placing the new-line characters in the correct place so that the ASCII file appears correctly. See Section 11.3. BORIS staff developed software to extract needed information from the data files and inventory the ER-2 navigation data in the relational data base.

14.2 Software Access
The software developed by BORIS staff can be obtained by contacting BORIS personnel or the ORNL DAAC.

15. Data Access

The level-0 ER-2 navigation data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information
For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification
Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics
http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data
Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans
The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products
The BOREAS level-0 ER-2 navigation data can be made available on 8-mm, Digital Archive Tape (DAT), or 9-track tapes at 1600 or 6250 Bytes Per Inch (BPI).

16.2 Film Products
Color aerial photographs and video records were made during data collection. The video record includes aircraft crew cabin intercom conversations and an audible tone that was initiated each time the sensors were triggered. The BOREAS data base contains an inventory of available BOREAS aircraft flight documentation, such as flight logs, videotapes, and photographs.

16.3 Other Products

Although the inventory is contained on the BOREAS CD-ROM set, the actual level-0 ER-2 navigation data are not. See Section 15 for information about how to obtain the data.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation
Ekstrand, R.E. and D. Wolf. 6 May 1992. INSPLOT.

Guillot, D. 1 April 1985. Cassette Data Format for the U-2 navigation recorder.

17.2 Journal Articles and Study Reports
Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102(D24): 28,731-28,770.

17.3 Archive/DBMS Usage Documentation
None.

18. Glossary of Terms

None.

19. List of Acronyms

```
A/D     - Analog-digital
AOCI    - Airborne Ocean Color Imager
ARC     - Ames Research Center
ARINC   - Aeronautical Radio, Inc.
ASAS    - Advanced Solid-State Array Spectroradiometer
ASCII   - American Standard Code for Information Interchange
AVIRIS  - Airborne Visible and Infrared Imaging Spectrometer
BIL     - Band Interleaved by Line
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
BPI     - Bytes Per Inch
CCT     - Computer Compatible Tape
CD-ROM  - Compact Disk-Read-Only Memory
CDU     - Control/Display Unit
DAAC    - Distributed Active Archive Center
DAT     - Digital Archive Tape
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
FFC     - Focused Field Campaign
FFC-T   - Focused Field Campaign - Thaw
GIS     - Geographic Information System
GMT     - Greenwich Mean Time
GPS     - Global Positioning System
GSFC    - Goddard Space Flight Center
HTML    - HyperText Markup Language
IFC     - Intensive Field Campaign
INS     - Inertial Navigation System
INU     - Inertial Navigation Unit
MAMS    - Multispectral Atmospheric Mapping Sensor
MAS     - MODS Airborne Simulator
MODIS   - Moderate-Resolution Imaging Spectrometer
MSU     - Mode Select Unit
NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NBS     - National Bureau of Standards
NSA     - Northern Study Area
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
PRT-5   - Precision Radiation Thermometer
RNAV    - Area Navigation
RSS     - Remote Sensing Science
S/D     - synchro-digital
SCSI    - Small Computer Serial Interface
SGI     - Silicon Graphics IRIX
SSA     - Southern Study Area
TACAN   - Tactical Air Navigation
TAS     - True Air Speed
TIMS    - Thermal Infrared Multispectral Scanner
TMS     - Thematic Mapper Simulator
URL     - Uniform Resource Locator
```

20. Document Information

20.1 Document Revision Date(s)
Written: 10-Mar-1998
Last Updated: 08-Jun-1999

20.2 Document Review Date(s)
BORIS Review: 17-Mar-1998
Science Review:

20.3 Document ID

20.4 Citation
When using these data, please include the following acknowledgment as well as citations of relevant papers in Section 17.2:
The BOREAS level-0 ER-2 navigation data were collected and processed from the original aircraft tapes by personnel of the Medium Altitude Aircraft Branch at NASA ARC. BORIS staff reviewed, repackaged, and documented the data received from ARC into the current product. The contributions of ARC and BORIS staff to enhancing and checking this data set are greatly appreciated.

Also, cite the BOREAS CD-ROM set as:
Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM. NASA, 2000.

20.5 Document Curator

20.6 Document URL

REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE September 2000	3. REPORT TYPE AND DATES COVERED Technical Memorandum

4. TITLE AND SUBTITLE

Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

BOREAS Level-0 ER-2 Navigation Data

6. AUTHOR(S)

Richard Strub, Roseanne Dominguez, and Jeffrey A. Newcomer

Forrest G Hall, Editor

5. FUNDING NUMBERS

923

RTOP: 923-462-33-01

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)

Goddard Space Flight Center
Greenbelt, Maryland 20771

8. PEFORMING ORGANIZATION REPORT NUMBER

2000-03136-0

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS (ES)

National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

TM—2000–209891
Vol. 86

11. SUPPLEMENTARY NOTES

R. Strub and J.A. Newcomer: Raytheon ITSS; NASA Goddard Space Flight Center, Greenbelt, Maryland; R. Dominguez: ATAC, Inc., NASA Ames Research Center, Moffett Field, California

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Unclassified–Unlimited
Subject Category: 43
Report available from the NASA Center for AeroSpace Information,
7121 Standard Drive, Hanover, MD 21076-1320. (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The BOREAS Staff Science effort covered those activities that were BOREAS community-level activities or required uniform data collection procedures across sites and time. These activities included the acquisition, processing, and archiving of aircraft navigation/attitude data to complement the digital image data. The level-0 ER-2 navigation data files contain aircraft attitude and position information acquired during the digital image and photographic data collection missions. Temporally, the data were acquired from April to September 1994. Data were recorded at intervals of 5 seconds. The data are stored in tabular ASCII files.

14. SUBJECT TERMS

BOREAS, remote sensing science, ER-2 navigaton data.

15. NUMBER OF PAGES

17

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39.18
298-102